

Assessing the Impact of Genetic Testing on Diet and Athletic Performance: A Survey on Personalized Nutrition

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Abstract

Genetic testing has emerged as a tool for personalizing nutrition and athletic training by identifying individual genetic variations that influence metabolism, nutrient absorption, and physical performance. However, its effectiveness in optimizing athletic outcomes remains debated. This study aims to assess the impact of genetic testing on athletes' dietary habits, digestion, body composition, and performance, exploring the perceived benefits of personalized nutrition in sports. A cross-sectional survey was conducted among 448 athletes in Saudi Arabia, spanning various sports disciplines and competitive levels. The survey measured athletes' perceptions of genetic testing's impact on diet and performance using Likert-scale questions. The results indicate that the athletes moderately agreed that genetic testing influenced their dietary adjustments (mean = 3.69), with improved digestion and nutrient absorption being the most positively perceived outcome (mean = 4.01). However, the perceived impact on tailored diets was lower (mean = 2.95), and recovery time showed minimal improvement (mean = 2.92). Significant gender differences were observed in digestion ($p = .0086$) and body composition changes ($p < .0001$), with males reporting greater improvements. Athletes in artistic sports reported the most significant changes in body composition (mean = 4.36, $p = .0005$), while professionals had the highest perceived benefit from personalized diets (mean = 4.40, $p < .0001$). In conclusion, genetic testing shows promise in enhancing athletes' nutrition and performance, particularly in digestion and body composition. However, its impact remains limited in areas like recovery, highlighting the need for a holistic approach integrating genetic data with broader training and lifestyle strategies.

Introduction

Genetic testing refers to the analysis of genes, chromosomes, or proteins to identify genetic variations that may influence various traits, including metabolism, nutrient absorption, muscle function, and recovery capacity [1,2]. With advancements in genomics, genetic testing has become accessible and applicable to numerous fields, including sports science and nutrition [3,4]. By identifying genetic variants linked to nutrient metabolism and physical performance, genetic testing allows for a more tailored approach to diet and training, ultimately enhancing athletic outcomes [5,6].

Genetic testing, which analyzes an individual's DNA to identify specific genetic variations, has gained significant attention in recent years, particularly in the fields of health, fitness, and nutrition [7]. By examining genetic markers, genetic testing provides valuable insights into how an individual's body functions at a molecular level, revealing predispositions to various health conditions, dietary needs, and physical capabilities [8]. For athletes, this tool has the potential to revolutionize dietary strategies and training regimens, allowing for a more personalized approach to optimizing performance and overall health [9].

For athletes, genetic testing can provide insights into how their bodies respond to different nutrients and exercise stimuli. For example, certain genetic markers can determine how efficiently an individual metabolizes carbohydrates, fats, and proteins, or how well their body processes micronutrients like vitamins and minerals [10,11]. Additionally, genetic variations can affect muscle composition, injury risk, and recovery times [12,13], all of which are critical factors in athletic performance. With this information, athletes and their coaches can design personalized nutrition and training programs that align with their genetic predispositions, enhancing performance while reducing the risk of injury.

Personalized nutrition, also known as precision nutrition, emphasizes tailoring dietary recommendations to an individual's unique genetic profile [14,15]. Traditional dietary guidelines often follow a generalized approach, which may not consider the genetic differences that affect how people respond to food and exercise. Genetic testing allows for more individualized dietary interventions, taking into account specific genetic factors that influence metabolism, nutrient absorption, and energy expenditure [16-18].

In the context of sports, genetic testing can help athletes understand how their bodies react to different diets and training programs [19]. For instance, some athletes may have a genetic predisposition to be better suited for

endurance-based sports, while others may be genetically inclined toward strength or power-based activities. Genetic markers such as the ACTN3 gene, which is linked to muscle fiber type, can provide insights into whether an athlete is more likely to excel in sprinting or endurance events [20]. Similarly, genes like PPARA, which are involved in fat metabolism, can influence an athlete's ability to perform in endurance activities by optimizing fat utilization for energy [21].

The potential benefits of genetic testing for athletes go beyond diet and performance optimization. By understanding their genetic predispositions, athletes can gain a competitive edge, tailoring their nutrition and training plans to their specific genetic strengths and weaknesses [7]. This personalized approach can lead to enhanced energy levels, improved recovery times, and optimal body composition, all of which are crucial for achieving peak performance in competitive sports.

Moreover, genetic testing can help athletes manage injury risks and recovery processes more effectively. Certain genetic variants are associated with a higher likelihood of soft tissue injuries or delayed recovery times [22-24]. Knowing this information allows athletes to adopt preventive measures, such as adjusting their training intensity or incorporating specific nutrients that aid in muscle repair and inflammation reduction.

In addition to performance benefits, genetic testing can address common nutritional challenges faced by athletes, such as micronutrient deficiencies or metabolic inefficiencies. For example, some athletes may have a genetic predisposition for poor absorption of vitamins like vitamin D, which plays a critical role in bone health and muscle function [25]. With genetic insights, athletes can adjust their supplementation strategies to meet their unique needs and avoid deficiencies that could impair their performance.

The growing interest in genetic testing within the athletic community reflects the increasing demand for personalized approaches to nutrition and performance. By moving away from generalized dietary guidelines, athletes can optimize their nutrition based on their genetic makeup, leading to more effective results both on and off the field. The insights gained from studying the impact of genetic testing on athletes' diets and performance can also have broader implications for public health, promoting the idea of personalized nutrition across various populations.

Given the rising importance of personalized nutrition and the potential advantages of genetic testing in optimizing athletic performance, this study aims to assess the impact of genetic testing on athletes' diets and performance. By conducting a survey on personalized nutrition, this research will explore how genetic testing influences dietary choices and performance outcomes, providing valuable insights into the role of genetics in sports nutrition and offering recommendations for more individualized approaches to athletic training and nutrition.

Background

Several studies [26-29] have highlighted the role of genetic testing in identifying variations in nutrient metabolism. For instance, Celis-Morales et al. [30] demonstrated that personalized dietary advice based on genetic testing led to improved health outcomes compared to general dietary guidelines. In their study, participants who received genetic information tailored to their metabolic profiles showed better adherence to dietary recommendations and greater improvements in cardiovascular health markers. Similarly, studies [10,31,32] found that athletes who adjusted their macronutrient intake based on genetic predispositions—such as carbohydrate or fat sensitivity—achieved better performance outcomes compared to those following standardized diets. These findings suggest that genetic testing can offer significant advantages in optimizing nutrient intake for individual metabolic needs.

However, not all studies have shown such positive results. Arkadianos et al. [33] conducted a randomized controlled trial comparing personalized diets based on genetic testing with conventional diets and found no significant difference in weight loss outcomes or metabolic improvements between the two groups. This raises questions about the extent to which genetic information can lead to meaningful dietary changes, particularly when other factors such as lifestyle and behavioral patterns are not adequately addressed.

The application of genetic testing in sports has also produced mixed results. Studies like those conducted by Pickering and Kiely [19] have focused on genetic markers such as the ACTN3 gene, which influences muscle fiber composition and is often linked to power versus endurance athletic performance. Their research demonstrated that athletes who tailored their training programs to their genetic predispositions—such as focusing on sprinting or endurance training based on ACTN3 variants—showed improved performance outcomes compared to those following traditional, non-personalized programs. This supports the idea that genetic testing can provide a framework for optimizing athletic performance by aligning training regimens with genetic strengths.

In contrast, Varillas-Delgado et al. [34] found limited benefits of genetic testing in athletic performance, particularly when it came to complex traits like endurance, recovery, and injury prevention. Their study emphasized that while genetic factors do play a role, they are only one piece of the puzzle, and environmental factors, such as training load, nutrition, and recovery protocols, have a far more significant impact on performance outcomes. These findings caution against over-reliance on genetic testing, suggesting that its utility

may be limited unless integrated with comprehensive training and nutritional strategies.

A major challenge in applying genetic testing to personalized nutrition and athletic performance is the variability in genetic data interpretation. Studies often use different genetic markers, making it difficult to standardize recommendations or draw comparisons across research. Furthermore, the ethical considerations regarding genetic testing, such as data privacy and potential misuse of genetic information, remain ongoing concerns. Studies like those by Vlahovich et al. [35] highlight the need for clearer guidelines in how genetic data is used, particularly in competitive sports, where the line between personalized nutrition and performance enhancement may blur.

Overall, while genetic testing holds promise in tailoring nutrition and training plans to individual needs, the evidence is mixed. While some studies show clear benefits in improving nutrient metabolism and aligning training programs with genetic predispositions, others highlight the limitations of genetic testing as a stand-alone tool. More research is needed to fully understand how genetic testing can be effectively integrated into comprehensive nutrition and athletic performance strategies, considering both genetic and environmental factors.

Methods

A cross-sectional survey design was adopted in this study. The selection of different approaches and the procedures adopted are explained in the following sections.

Study settings and participants

The survey will be conducted online to ensure broad participation across different athletic disciplines and geographical regions. The target population for the study will consist of athletes from different sports clubs across Saudi Arabia, who engage in regular training, both amateur and professional, across a range of sports disciplines such as endurance sports (e.g., running, cycling, swimming), strength-based sports (e.g., weightlifting, bodybuilding), and team sports (e.g., football, basketball, rugby). This diverse approach will enable a comprehensive understanding of how probiotics and prebiotics impact different types of athletic performance and digestive health outcomes.

The survey will be distributed through various platforms, including social media, athletic forums, and sports clubs or organizations. In addition, outreach will be conducted to professional sports associations and training facilities to ensure participation from a wide range of athletes, including those from different regions and levels of competitiveness.

Participant Inclusion Criteria Participants must meet the following criteria:

- **Age:** Athletes aged 18 years and above will be eligible to participate. This age range ensures that participants have independent dietary control and are able to provide informed consent.
- **Training Regimen:** Participants must engage in structured athletic training for a minimum of four hours per week. This criterion is designed to focus on individuals who have an active training regimen, which is more likely to place physical stress on their bodies and influence gut health.
- **Dietary Awareness:** Athletes were required to have basic knowledge of their dietary habits, including whether they had undergone genetic testing for nutrition or performance-related factors. This criterion ensured that participants were familiar with their diet and potentially open to personalized nutrition strategies.
- **Health Status:** Only athletes who reported no diagnosed chronic gastrointestinal or metabolic conditions (e.g., Crohn's disease, diabetes) were included, as such conditions could confound the relationship between diet, genetic factors, and athletic performance.

Participant Exclusion Criteria Participants will be excluded from the study if they:

- Have taken antibiotics within the past three months, as antibiotics significantly alter the gut microbiota and could skew the results regarding probiotics and prebiotics' effects.
- Are currently on a medically prescribed diet for gastrointestinal or metabolic conditions (e.g., celiac disease, irritable bowel syndrome).
- Are pregnant or breastfeeding, as hormonal changes during these periods can affect both gut health and physical performance, potentially confounding the study results.

Sampling

A stratified random sampling method [36] is employed in this study to ensure a representative sample of the Saudi Arabian athletes across different regions and demographic groups. The sample is stratified based on key variables, including, sports discipline, level of competition, age, gender, and education. This approach ensures that all significant subgroups within the population are adequately represented in the study. Within each stratum, participants are randomly selected to reduce selection bias and increase the generalizability of the findings. The target sample size is approximately 400 participants (based on an estimated sample of 383 calculated using

Cochran's formula [37], distributed proportionally across the selected sports clubs. This sample size is designed to provide sufficient statistical power for analyzing variations in participants perceptions.

Questionnaire design

is designed to gather insights on how athletes utilize genetic testing for dietary optimization and the perceived impact on their performance. The questionnaire is structured to capture both quantitative and qualitative data, making use of Likert-scale questions to measure the degree of agreement or disagreement with specific statements. It begins with an introductory section explaining the study's purpose, eligibility criteria, confidentiality, and voluntary participation, ensuring informed consent and clarity for the participants. The survey is divided into several sections. The participant information section collects demographic details such as age, gender, sport discipline, competition level, and years of involvement in sports, allowing for categorization and comparison across different athlete groups. The next section focuses on the utilization of genetic testing results [38,39], where athletes are asked about their experiences with genetic testing and how they have applied the results to make dietary adjustments, including macronutrient intake and supplement choices. This section also probes the athletes' consultation with nutritionists or dietitians, highlighting the level of professional guidance received.

The impact on diet section investigates whether genetic testing has led to more individualized diets, improvements in digestion, and changes in body composition [40-42]. This is followed by the impact on performance section, which examines athletes' perceptions of improved athletic performance, recovery times, injury prevention, and mental focus as a result of personalized nutrition. The survey also assesses the prevalence of genetic testing among athletes and gathers opinions on its increasing adoption in sports training programs. The final section explores the challenges and benefits of implementing dietary changes based on genetic testing, including the cost, guidance, and perceived benefits of personalized nutrition. This comprehensive design ensures a thorough understanding of the role genetic testing plays in athletes' dietary habits and performance outcomes.

A certified translator [43] translated the questionnaire from English to Arabic. The accuracy of the translated version was subsequently validated by three professors from the Health department at King Faisal University. They proposed several grammatical adjustments, which were incorporated into the Arabic version of the questionnaire. To further refine the instrument, a pilot study was conducted with a sample of 14 athletes. The data collected from this exploratory study were analyzed, and the Cronbach's alpha coefficient for all items was calculated. The coefficient exceeded 0.7, indicating robust internal consistency and reliability of the questionnaire [44].

Data collection

Data for this study were collected over four weeks using a structured survey questionnaire, available in both English and Arabic. The questionnaire was distributed exclusively through online platforms to ensure broad accessibility and convenience for participants across various regions in Saudi Arabia, including urban, suburban, and rural areas. The online distribution leveraged social media, email networks, and community forums to reach a diverse population. This digital approach facilitated the collection of comprehensive data ensuring participants could complete the survey at their convenience. At the end of four weeks, 459 responses were received, out of which 11 responses were incomplete. After removing incomplete responses, a final sample of 448 was considered for data analysis.

Data Analysis

To achieve the study's objectives, the data were analyzed using the Statistical Package for the Social Sciences (SPSS, IBM Version 24). Descriptive statistics, including means and standard deviations, were employed to present the demographic characteristics of the participants. Additionally, a two-sample t-test with unequal variances and a one-way ANOVA were conducted to analyze the data further.

Ethical considerations

The study received approval from the research ethics committee at King Faisal University (KFU-REC-2024-OCT-ETHICS2704). Informed consent was obtained from all participants prior to their involvement. To ensure confidentiality and data security, responses were anonymized, and data were stored on secure servers. The study adhered to all relevant ethical standards, with no reported conflicts of interest or external funding sources, thereby upholding research integrity and minimizing bias.

Results

The demographic data presented in Table 1 reveals that the study sample is composed of 58.7% males and 41.3% females. In terms of sports participation, team sports are the most popular, with 37.9% of athletes involved, followed by endurance sports (26.1%) and combat sports (13.8%). Strength sports (11.2%), motor sports (7.8%), and artistic sports (3.1%) represent smaller portions of the sample. The majority of participants have been engaged in their respective sports for 4-6 years (39.3%), while 29.2% have 1-3 years of experience. A smaller proportion has more extensive experience, with 17.2% participating for 7-10 years and 14.3% for over 10 years. In terms of competitive level, the sample is nearly evenly split between amateurs (40.6%) and semi-professionals (41.5%), with professionals making up 17.9% of the participants. Age distribution shows that over half of the participants (53.6%) are in the 18-29 age group, with 32.4% aged 30-39, 12.1% aged 40-49, and only 2% aged 50 or older. This demographic profile suggests a predominantly young, male sample with a broad range of sports participation and competitive levels.

Table 1. Participants demographics

	Variables	N	Relative frequency
Gender	Male	263	58.7%
	Female	185	41.3%
Type of Sports	Artistic Sports	14	3.1%
	Combat Sports	62	13.8%
	Endurance Sports	117	26.1%
	Motor Sports	35	7.8%
	Strength Sports	50	11.2%
	Team Sports	170	37.9%
Engagement with sports (in years)	1-3	131	29.2%
	4-6	176	39.3%
	7-10	77	17.2%
	> 10	64	14.3%
Competitive level	Amateur	182	40.6%
	Semi-Professional	186	41.5%
	Professional	80	17.9%
Age (in years)	18-29	240	53.6%
	30-39	145	32.4%
	40-49	54	12.1%
	> = 50	9	2.0%

The data in Table 2 highlights athletes' perceptions of the impact of genetic testing on their diet and athletic performance. On average, athletes moderately agree that genetic testing influenced their dietary adjustments, with a mean score of 3.69. However, the effectiveness of genetic testing in making their diets more tailored and individualized is rated lower, with a mean of 2.95, suggesting limited success in achieving fully personalized nutrition. In terms of physical benefits, athletes report a significant improvement in digestion and nutrient absorption, with the highest mean score of 4.01, indicating that genetic testing has had a noticeable positive impact in this area. Changes in body composition, such as muscle gain or fat loss, are rated moderately (3.65), suggesting that some athletes experienced physical changes due to dietary adjustments. Regarding athletic performance, athletes indicate a moderate improvement (mean: 3.78) following dietary changes based on genetic testing. Similarly, mental focus and cognitive functions saw a modest boost (mean: 3.77). However, the impact on recovery time is rated lower, with a mean of 2.92, suggesting that athletes may not perceive significant improvements in recovery post-exercise.

Table 2. Impact of genetic testing on diet and athletic performance

Factors (Scale: 1: Strongly disagree; 5: Strongly agree)	Mean Values
Utilization of genetic testing results in making dietary adjustments	3.69
Diet has become more tailored and individualized	2.95
Improved digestion and nutrient absorption	4.01
Changes in body composition due to dietary adjustments	3.65
Improved athletic performance	3.78
Improved recovery time	2.92
Improved mental focus and cognitive functions	3.77

The t-test results in Table 3 reveal gender differences in athletes' perceptions of the impact of genetic testing on diet and performance. While males and females reported similar use of genetic testing for making dietary adjustments (mean: 3.74 for males, 3.62 for females, $p = .1072$) and tailoring their diets (mean: 2.97 for males, 2.93 for females, $p = .7977$), significant differences emerged in other areas. Males perceived greater improvements in digestion and nutrient absorption (mean: 4.12) compared to females (mean: 3.84), with a statistically significant difference ($p = .0086$). Similarly, males reported more pronounced changes in body composition due to dietary adjustments (mean: 4.22), while females rated these changes much lower (mean: 2.85), with a highly significant difference ($p < .0001$). No significant gender differences were found in perceptions of athletic performance improvements (mean: 3.80 for males, 3.75 for females, $p = .6077$), recovery time (mean: 2.90 for males, 2.96 for females, $p = .5821$), or mental focus and cognitive functions (mean: 3.75 for males, 3.81 for females, $p = .6264$).

Table 3. T-test results assessing difference between participants perceptions on using genetic testing results - based on their gender

Factors	Gender	N	Mean	Variance	p-value
Utilization of genetic testing results in making dietary adjustments	Male	263	3.74	0.64	.1072
	Female	185	3.62	0.53	
Diet has become more tailored and individualized	Male	263	2.97	2.82	.7977
	Female	185	2.93	2.35	
Improved digestion and nutrient absorption	Male	263	4.12	0.90	.0086*
	Female	185	3.84	1.58	
Changes in body composition due to dietary adjustments	Male	263	4.22	1.14	< .0001*
	Female	185	2.85	1.89	
Improved athletic performance	Male	263	3.80	1.19	.6077
	Female	185	3.75	1.47	
Improved recovery time	Male	263	2.90	1.50	.5821
	Female	185	2.96	1.51	
Improved mental focus and cognitive functions	Male	263	3.75	1.74	.6264
	Female	185	3.81	1.54	

* Statistically significant difference at .05 confidence interval

The ANOVA results in Table 4 reveal differences in athletes' perceptions of genetic testing's impact based on sport type. For utilization of genetic testing in dietary adjustments, artistic sports participants had the highest mean score (3.95), while team sports athletes scored the lowest (3.65), with no significant difference ($p = .1154$). Similarly, artistic sports athletes reported the highest mean for tailored diets (3.86) compared to team sports (2.81), also lacking significance ($p = .2907$). In terms of improved digestion and nutrient absorption, artistic sports participants scored 4.00, while combat sports athletes had the highest mean (4.26), with no significant differences ($p = .3083$). Notably, changes in body composition due to dietary adjustments were significantly perceived among artistic sports participants (mean: 4.36, $p = .0005$). Perceptions of improved athletic performance were consistent across groups, with no significant differences ($p = .8829$). For recovery time, scores remained close with no significant differences ($p = .8602$), and in mental focus and cognitive functions, artistic sports athletes had the lowest mean (3.21), while strength sports participants had the highest (4.04), but this variation was not significant ($p = .2191$). Overall, the significant finding regarding body composition changes in artistic sports participants highlights an area for tailored dietary interventions.

Table 4. ANOVA results assessing difference between participants perceptions on using genetic testing results - based on type of sport played

Factors	Type of Sports	N	Mean	Variance	p-value
Utilization of genetic testing results in making dietary adjustments	Artistic Sports	14	3.95	0.54	.1154
	Combat Sports	62	3.61	0.75	
	Endurance Sports	117	3.67	0.70	
	Motor Sports	35	3.70	0.55	
	Strength Sports	50	3.95	0.44	
	Team Sports	170	3.65	0.51	
Diet has become more tailored and individualized	Artistic Sports	14	3.86	2.29	.2907
	Combat Sports	62	2.95	2.74	
	Endurance Sports	117	3.03	2.67	
	Motor Sports	35	2.89	2.52	
	Strength Sports	50	3.04	2.77	
	Team Sports	170	2.81	2.52	
Improved digestion and nutrient absorption	Artistic Sports	14	4.00	1.08	.3083
	Combat Sports	62	4.26	0.95	
	Endurance Sports	117	3.89	1.29	
	Motor Sports	35	3.83	1.15	
	Strength Sports	50	3.94	1.24	
	Team Sports	170	4.05	1.22	
Changes in body composition due to dietary adjustments	Artistic Sports	14	4.36	1.02	.0005*
	Combat Sports	62	3.76	1.69	
	Endurance Sports	117	3.40	1.97	
	Motor Sports	35	4.49	0.96	
	Strength Sports	50	3.68	2.02	
	Team Sports	170	3.55	1.97	
Improved athletic performance	Artistic Sports	14	3.71	0.99	.8829
	Combat Sports	62	3.79	1.28	
	Endurance Sports	117	3.71	1.26	
	Motor Sports	35	3.97	1.32	
	Strength Sports	50	3.86	1.39	
	Team Sports	170	3.76	1.36	
Improved recovery time	Artistic Sports	14	2.86	1.82	.8602
	Combat Sports	62	2.84	1.35	
	Endurance Sports	117	2.88	1.50	
	Motor Sports	35	3.14	2.01	
	Strength Sports	50	2.86	1.47	
	Team Sports	170	2.96	1.47	
Improved mental focus and cognitive functions	Artistic Sports	14	3.21	1.87	.2191
	Combat Sports	62	3.90	1.47	
	Endurance Sports	117	3.83	1.38	
	Motor Sports	35	3.69	1.93	
	Strength Sports	50	4.04	1.63	
	Team Sports	170	3.66	1.82	

* Statistically significant difference at .05 confidence interval

The ANOVA results in Table 5 examine differences in perceptions of genetic testing's impact based on age. For the utilization of genetic testing in dietary adjustments, participants aged 18-29 reported the highest mean score (3.72), while those aged 50 and above had the lowest (3.44), but these differences were not statistically significant ($p = .2549$). In terms of diet tailoring, younger participants scored 2.81 compared to higher scores from older age groups, yet this was also not significant ($p = .1524$). Regarding improved digestion and nutrient absorption, the 18-29 age group again had the highest mean (4.08), with no significant differences ($p = .3728$). For changes in body composition, younger athletes scored 3.71, while those aged 40-49 scored the highest (3.87), with no significant differences observed ($p = .2382$). Perceptions of athletic performance were similar across age groups, with the 18-29 group scoring 3.87 ($p = .3227$). The mean scores for recovery time and mental focus were also consistent, showing no significant differences ($p = .7572$ and $p = .1661$, respectively). Overall, while younger athletes reported higher scores across most factors, none of the differences were statistically significant, indicating a similar perception of genetic testing's impact across age groups.

Table 5. ANOVA results assessing difference between participants perceptions on using genetic testing results - based on age

Factors	Age (in years)		Mean	Variance	p-value
Utilization of genetic testing results in making dietary adjustments	18-29	240	3.72	0.59	.2549
	30-39	145	3.62	0.61	
	40-49	54	3.83	0.58	
	>=50	9	3.44	0.47	
Diet has become more tailored and individualized	18-29	240	2.81	2.68	.1524
	30-39	145	3.10	2.41	
	40-49	54	3.26	2.80	
	>=50	9	2.67	2.50	
Improved digestion and nutrient absorption	18-29	240	4.08	1.14	.3728
	30-39	145	3.95	1.21	
	40-49	54	3.87	1.40	
	>=50	9	3.67	1.25	
Changes in body composition due to dietary adjustments	18-29	240	3.71	1.90	.2382
	30-39	145	3.48	1.88	
	40-49	54	3.87	2.00	
	>=50	9	3.56	1.53	
Improved athletic performance	18-29	240	3.87	1.22	.3227
	30-39	145	3.66	1.52	
	40-49	54	3.70	1.16	
	>=50	9	3.78	0.94	
Improved recovery time	18-29	240	2.93	1.43	.7572
	30-39	145	2.88	1.62	
	40-49	54	2.94	1.53	
	>=50	9	3.33	1.75	
Improved mental focus and cognitive functions	18-29	240	3.88	1.57	.1661
	30-39	145	3.72	1.69	
	40-49	54	3.48	1.84	
	>=50	9	3.44	1.78	

* Statistically significant difference at .05 confidence interval

The ANOVA results in Table 6 evaluate differences in perceptions of genetic testing's impact based on competitive level. Significant differences were found in the utilization of genetic testing results for dietary adjustments, with amateurs scoring the lowest (mean: 3.53), while semi-professionals (3.72) and professionals (3.99) reported higher utilization ($p < .0001$). Similarly, in terms of whether diets have become more tailored and individualized, professionals had a significantly higher mean score (4.40) compared to amateurs (1.76), indicating that competitive level influences perceptions of personalized nutrition ($p < .0001$).

Table 6. ANOVA results assessing difference between participants perceptions on using genetic testing results - based on experience of competitive level

Factors	Variables	N	Mean	Variance	p-value
Utilization of genetic testing results in making dietary adjustments	Amateur	182	3.53	0.49	< .0001*
	Semi-Professional	186	3.72	0.64	
	Professional	80	3.99	0.60	
Diet has become more tailored and individualized	Amateur	182	1.76	1.30	< .0001*
	Semi-Professional	186	3.49	2.11	

	Professional	80	4.40	0.83	
Improved digestion and nutrient absorption	Amateur	182	4.01	1.29	.9945
	Semi-Professional	186	4.00	1.11	
	Professional	80	4.00	1.19	
Changes in body composition due to dietary adjustments	Amateur	182	3.76	1.76	.3771
	Semi-Professional	186	3.56	2.05	
	Professional	80	3.63	1.86	
Improved athletic performance	Amateur	182	3.88	1.17	.1829
	Semi-Professional	186	3.75	1.45	
	Professional	80	3.61	1.23	
Improved recovery time	Amateur	182	2.88	1.41	.8474
	Semi-Professional	186	2.96	1.59	
	Professional	80	2.94	1.55	
Improved mental focus and cognitive functions	Amateur	182	3.84	1.70	.0767
	Semi-Professional	186	3.83	1.58	
	Professional	80	3.48	1.67	

* *Statistically significant difference at .05 confidence interval*

For improved digestion and nutrient absorption, all groups had similar means (amateurs: 4.01, semi-professionals: 4.00, professionals: 4.00) with no significant differences ($p = .9945$). Likewise, there were no significant differences in changes in body composition ($p = .3771$) or improved athletic performance ($p = .1829$), though amateurs (3.88) scored slightly higher than semi-professionals (3.75) and professionals (3.61). All groups reported comparable means for recovery time ($p = .8474$) and mental focus and cognitive functions ($p = .0767$). Overall, competitive level significantly influences perceptions of genetic testing benefits, particularly in dietary adjustments and individualization, while perceptions regarding digestion and nutrient absorption remained consistent across all groups.

Discussion

The findings of this study underscore the potential of genetic testing in influencing athletes' dietary habits and performance, although its effectiveness remains nuanced. Athletes reported moderate improvements in dietary adjustments and performance metrics, aligning with previous research supporting the personalized approach enabled by genetic testing in sports nutrition. However, the mixed outcomes suggest a complex interplay between genetic predispositions and factors such as lifestyle, training, and psychological engagement, reflecting findings from earlier studies discussed in the introduction and background. Several studies have highlighted the benefits of personalized nutrition based on genetic information. Celis-Morales et al. [30] found that individuals receiving dietary advice tailored to their genetic profiles showed better adherence and health improvements compared to those following generalized guidelines. Similarly, athletes in this study moderately agreed that genetic testing led to more tailored diets (mean = 2.95) and improvements in digestion and nutrient absorption (mean = 4.01). These results align with Pickering and Kiely's [19] findings, where athletes who aligned their training and nutrition with genetic markers such as the ACTN3 and PPARA genes showed improved performance outcomes.

However, this study also revealed limitations in achieving fully individualized nutrition and significant physical improvements through genetic testing. For instance, while athletes reported moderate improvements in body composition (mean = 3.65) and athletic performance (mean = 3.78), these results are not as pronounced as expected. This is consistent with the findings of Arkadianos et al. [33], who found no significant differences in metabolic outcomes between participants on personalized genetic diets and those on conventional diets. Their study raised questions about whether genetic information alone is sufficient to drive meaningful dietary changes, suggesting that behavioral factors and adherence to recommendations play a critical role in the outcomes of such interventions.

Moreover, the effectiveness of genetic testing in improving recovery times was rated low (mean = 2.92), which echoes the findings of Varillas-Delgado et al. [34], who found limited benefits of genetic testing in enhancing complex traits such as recovery and endurance. This suggests that while genetic predispositions may provide insights into certain aspects of performance, other factors like training load, recovery protocols, and psychological stress are equally, if not more, important in determining outcomes. It emphasizes that genetic testing should be integrated into a holistic approach to athlete performance management, rather than being used in isolation.

Gender differences were notable in this study, with males reporting significantly greater improvements in digestion and body composition due to dietary adjustments compared to females ($p = .0086$ and $p < .0001$, respectively). This could be linked to differences in how genetic factors interact with male and female physiology, particularly regarding nutrient absorption and muscle gain. These results align with previous studies that identified gender-specific responses to genetic testing [25]. However, no significant gender differences were found in athletic performance or recovery times, suggesting that while genetic testing may influence specific physical outcomes differently in men and women, overall performance benefits are experienced more uniformly across genders.

The study also revealed variations in how athletes from different sports disciplines perceived the impact of genetic testing. Artistic sports participants reported the most significant changes in body composition (mean = 4.36, $p = .0005$), suggesting that

athletes in sports requiring precision and physical control may benefit more from tailored dietary interventions based on genetic insights. In contrast, team sports athletes reported lower utilization of genetic testing results (mean = 3.65), which might indicate that in sports where collective dynamics are prioritized over individual physical optimization, the perceived benefits of genetic testing are diminished. This aligns with earlier studies, such as those by Pickering and Kiely [19], which found that the effectiveness of genetic testing can vary depending on the type of sport and its specific physical demands.

In terms of the athletes' competitive levels, professionals reported significantly higher utilization of genetic testing results for dietary adjustments (mean = 3.99, $p < .0001$) and more tailored diets (mean = 4.40, $p < .0001$) compared to amateurs. This is consistent with the findings of Vlahovich et al. [35], who highlighted that professional athletes are more likely to integrate genetic testing into their training and nutrition regimes, as they have access to better resources and professional guidance.

Overall, while the results of this study support the potential benefits of genetic testing in sports nutrition, they also highlight the limitations and challenges of its application. The variability in outcomes across different genders, sports, and competitive levels suggests that genetic testing should not be viewed as a one-size-fits-all solution. Instead, it should be integrated into a comprehensive approach that considers genetic predispositions alongside training regimens, environmental factors, and psychological aspects to maximize its potential benefits. Further research is needed to refine how genetic insights can be more effectively incorporated into personalized nutrition strategies, ensuring that athletes can optimize their performance in a sustainable and holistic manner.

Implications

Theoretically, this study contributes to the growing body of knowledge on personalized nutrition by reinforcing the role of genetic testing in tailoring dietary and training interventions for athletes. It supports theories related to the interaction between genetic predispositions and individual metabolism, nutrient absorption, and performance, while also highlighting the limitations of relying solely on genetic information to achieve significant performance gains. Practically, the findings underscore the need for athletes and coaches to integrate genetic insights with holistic training programs that consider environmental, psychological, and behavioral factors. For sports practitioners, genetic testing offers valuable data to fine-tune nutrition and training strategies, but it should be applied in conjunction with expert guidance, individualized recovery protocols, and lifestyle modifications to achieve optimal results. This practical approach ensures that genetic information is leveraged effectively without over-reliance, enhancing both performance and long-term health outcomes.

Limitations

This study has several limitations that should be acknowledged. First, the cross-sectional survey design captures athletes' perceptions at a single point in time, limiting the ability to assess long-term impacts of genetic testing on dietary habits and performance. Additionally, the reliance on self-reported data introduces the possibility of bias, as athletes' perceptions may not accurately reflect objective changes in performance or body composition. The sample, while diverse in terms of sports and demographics, is geographically limited to Saudi Arabia, which may reduce the generalizability of the findings to other regions or athletic populations. Moreover, the study did not control for other variables that can influence performance outcomes, such as training intensity, psychological factors, or existing nutrition habits, which could confound the effects attributed to genetic testing. Finally, the study's focus on perceived benefits rather than measurable performance metrics leaves open the question of whether the reported improvements translate into significant, quantifiable athletic gains. Future research could address these limitations by employing longitudinal designs, objective performance measures, and more geographically diverse samples.

Conclusion

In conclusion, this study highlights the potential benefits and limitations of genetic testing in shaping personalized nutrition and athletic performance. While athletes reported moderate improvements in digestion, body composition, and overall performance, the findings suggest that genetic testing alone is not sufficient to drive significant performance enhancements. The results indicate that integrating genetic insights with comprehensive training regimens and considering environmental and psychological factors is essential for maximizing the benefits of personalized nutrition. Moreover, the variability in outcomes based on gender, sport type, and competitive level emphasizes the need for a tailored, holistic approach rather than a one-size-fits-all application of genetic testing. Overall, while genetic testing shows promise in optimizing athletic outcomes, its utility should be viewed as one part of a broader, multifactorial strategy for improving health and performance.

Availability of data

Data cannot be shared openly to protect study participant privacy.

Authors' contributions and materials

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

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Conflict of Interest

The authors declare that there is no actual or potential conflict of interest.

References

1. Samadder NJ, Riegert-Johnson D, Boardman L, Rhodes D, Wick M, Okuno S, et al. Comparison of Universal Genetic Testing vs Guideline-Directed Targeted Testing for Patients with Hereditary Cancer Syndrome. *JAMA Oncology* [Internet]. 2020 Oct 30;7(2):230. Available from: <https://doi.org/10.1001/jamaoncol.2020.6252>
2. Nguyen-Dumont T, Karpinski P, Sasiadek MM, et al. Genetic testing in Poland and Ukraine: should comprehensive germline testing of BRCA1 and BRCA2 be recommended for women with breast and ovarian cancer? *Genetics Research*. 2020;102:e6. doi:10.1017/S0016672320000075
3. Malsagova KA, Kopylov AT, Sinitsyna AA, Stepanov AA, Izotov AA, Butkova TV, Chingin K, Klyuchnikov MS, Kaysheva AL. Sports Nutrition: Diets, Selection Factors, Recommendations. *Nutrients*. 2021; 13(11):3771. <https://doi.org/10.3390/nu13113771>
4. Mullins VA, Bresette W, Johnstone L, Hallmark B, Chilton FH. Genomics in Personalized Nutrition: Can You “Eat for Your Genes”? *Nutrients*. 2020; 12(10):3118. <https://doi.org/10.3390/nu12103118>
5. Yang J. Design Tailored Nutrition and Weight Control Recommendations Using Nutrigenetics and FFQ. In: Lecture notes in computer science [Internet]. 2020. p. 169–76. Available from: https://doi.org/10.1007/978-3-030-61951-0_16
6. Moore JB. From personalised nutrition to precision medicine: the rise of consumer genomics and digital health. *Proceedings of the Nutrition Society*. 2020;79(3):300-310. doi:10.1017/S0029665120006977
7. Naureen Z, Miggiano GAD, Aquilanti B, et al. Genetic test for the prescription of diets in support of physical activity. *Acta Biomed*. 2020;91(13-S):e2020011. Published 2020 Nov 9. doi:10.23750/abm.v91i13-S.10584
8. Institute of Medicine (US) Committee on Assessing Interactions Among Social, Behavioral, and Genetic Factors in Health; Hernandez LM, Blazer DG, editors. *Genes, Behavior, and the Social Environment: Moving Beyond the Nature/Nurture Debate*. Washington (DC): National Academies Press (US); 2006. 3, Genetics and Health. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK19932/>
9. Singar S, Nagpal R, Arjmandi BH, Akhavan NS. Personalized Nutrition: Tailoring Dietary Recommendations through Genetic Insights. *Nutrients*. 2024; 16(16):2673. <https://doi.org/10.3390/nu16162673>
10. Guest NS, Horne J, Vanderhout SM, El-Sohemy A. Sport Nutrigenomics: Personalized Nutrition for Athletic Performance. *Frontiers in Nutrition* [Internet]. 2019 Feb 19;6. Available from: <https://doi.org/10.3389/fnut.2019.00008>
11. Castelletti S, Gray B, Basso C, Behr ER, Crotti L, Elliott PM, et al. Indications and utility of cardiac genetic testing in athletes. *European Journal of Preventive Cardiology* [Internet]. 2022 Apr 21; Available from: <https://doi.org/10.1093/eurjpc/zwac080>
12. Limongelli G, Nunziato M, D’Argenio V, Esposito MV, Monda E, Mazzaccara C, et al. Yield and clinical significance of genetic screening in elite and amateur athletes. *European Journal of Preventive Cardiology* [Internet]. 2020 Jul 2;28(10):1081–90. Available from: <https://doi.org/10.1177/2047487320934265>
13. Maciejewska-Skrendo A, Leźnicka K, Leońska-Duniec A, et al. Genetics of Muscle Stiffness, Muscle Elasticity and Explosive Strength. *J Hum Kinet*. 2020;74:143-159. Published 2020 Aug 31. doi:10.2478/hukin-2020-0027
14. Del Coso J, Hiam D, Houweling P, Pérez LM, Eynon N, Lucía A. More than a ‘speed gene’: ACTN3 R577X genotype, trainability, muscle damage, and the risk for injuries. *European Journal of Applied Physiology* [Internet]. 2018 Oct 16;119(1):49–60. Available from: <https://doi.org/10.1007/s00421-018-4010-0>
15. Bush CL, Blumberg JB, El-Sohemy A, Minich DM, Ordovás JM, Reed DG, et al. Toward the Definition of Personalized Nutrition: A Proposal by The American Nutrition Association. *Journal of the American College of Nutrition* [Internet]. 2019 Dec 19;39(1):5–15. Available from: <https://doi.org/10.1080/07315724.2019.1685332>
16. Hughes RL. A Review of the Role of the Gut Microbiome in Personalized Sports Nutrition. *Frontiers in Nutrition* [Internet]. 2020 Jan 10;6. Available from: <https://doi.org/10.3389/fnut.2019.00191>
17. Bashiardes S, Godneva A, Elinav E, Segal E. Towards utilization of the human genome and microbiome for personalized nutrition. *Current Opinion in Biotechnology* [Internet]. 2017 Dec 8;51:57–63. Available from: <https://doi.org/10.1016/j.copbio.2017.11.013>
18. Bordoni L, Gabbianelli R. Primers on nutrigenetics and nutri(epi)genomics: Origins and development of precision nutrition. *Biochimie* [Internet]. 2019 Mar 13;160:156–71. Available from: <https://doi.org/10.1016/j.biochi.2019.03.006>
19. Pickering C, Kiely J. Understanding Personalized Training Responses: Can Genetic Assessment Help? *The Open Sports Sciences Journal* [Internet]. 2017 Nov 30;10(1):191–213. Available from: <https://doi.org/10.2174/1875399x01710010191>
20. Baltazar-Martins G, Gutiérrez-Hellín J, Aguilar-Navarro M, et al. Effect of ACTN3 Genotype on Sports Performance, Exercise-Induced Muscle Damage, and Injury Epidemiology. *Sports (Basel)*. 2020;8(7):99. Published 2020 Jul 13. doi:10.3390/sports8070099
21. Lopez-Leon S, Tuvblad C, Forero DA. Sports genetics: the PPARA gene and athletes' high ability in endurance sports. A systematic review and meta-analysis. *Biol Sport*. 2016;33(1):3-6. doi:10.5604/20831862.1180170
22. Collins M, Raleigh SM. Genetic Risk Factors for Musculoskeletal Soft Tissue Injuries. *Medicine and Sport Science/Medicine and Sport* [Internet]. 2009 Jan 1;136–49. Available from: <https://doi.org/10.1159/000235701>

23. Baumert P, Lake MJ, Stewart CE, Drust B, Erskine RM. Genetic variation and exercise-induced muscle damage: implications for athletic performance, injury and ageing. *Eur J Appl Physiol.* 2016;116(9):1595-1625. doi:10.1007/s00421-016-3411-1
24. Brazier J, Antrobus MR, Herbert AJ, Callus PC, Khanal P, Stebbings GK, et al. Gene variants previously associated with reduced soft-tissue injury risk: Part 2 – Polygenic associations with elite status in Rugby. *European Journal of Sport Science* [Internet]. 2022 Dec 12;23(8):1779–88. Available from: <https://doi.org/10.1080/17461391.2022.2155877>
25. Wang TJ, Zhang F, Richards JB, et al. Common genetic determinants of vitamin D insufficiency: a genome-wide association study. *Lancet.* 2010;376(9736):180-188. doi:10.1016/S0140-6736(10)60588-0
26. Day KJ, Adamski MM, Dordevic AL, Murgia C. Genetic Variations as Modifying Factors to Dietary Zinc Requirements—A Systematic Review. *Nutrients.* 2017; 9(2):148. <https://doi.org/10.3390/nu9020148>
27. Zeisel SH. Precision (Personalized) Nutrition: Understanding Metabolic Heterogeneity. *Annual Review of Food Science and Technology* [Internet]. 2020 Jan 13;11(1):71–92. Available from: <https://doi.org/10.1146/annurev-food-032519-051736>
28. Cheng Y, Schlosser P, Hertel J, Sekula P, Oefner PJ, Spiekerkoetter U, et al. Rare genetic variants affecting urine metabolite levels link population variation to inborn errors of metabolism. *Nature Communications* [Internet]. 2021 Feb 11;12(1). Available from: <https://doi.org/10.1038/s41467-020-20877-8>
29. Vyas P, Singh D, Singh N, Kumar V, Dhaliwal HS. Nutrigenomics: Advances, Opportunities and Challenges in Understanding the Nutrient-Gene Interactions. *Current Nutrition & Food Science* [Internet]. 2018 Apr 6;14(2):104–15. Available from: <https://doi.org/10.2174/1573401313666170614094410>
30. Celis-Morales C, Livingstone KM, Marsaux CF, et al. Effect of personalized nutrition on health-related behaviour change: evidence from the Food4Me European randomized controlled trial. *Int J Epidemiol.* 2017;46(2):578-588. doi:10.1093/ije/dyw186
31. Amawi A, AlKasasbeh W, Jaradat M, Almasri A, Alobaidi S, Hammad AA, et al. Athletes’ nutritional demands: a narrative review of nutritional requirements. *Frontiers in Nutrition* [Internet]. 2024 Jan 18;10. Available from: <https://doi.org/10.3389/fnut.2023.1331854>
32. Kerksick CM, Wilborn CD, Roberts MD, Smith-Ryan A, Kleiner SM, Jäger R, et al. ISSN exercise & sports nutrition review update: research & recommendations. *Journal of the International Society of Sports Nutrition* [Internet]. 2018 Jan 5;15(1). Available from: <https://doi.org/10.1186/s12970-018-0242-y>
33. Arkadianos I, Valdes AM, Marinos E, Florou A, Gill RD, Grimaldi KA. Improved weight management using genetic information to personalize a calorie controlled diet. *Nutr J.* 2007;6:29. Published 2007 Oct 18. doi:10.1186/1475-2891-6-29
34. Varillas-Delgado D, Del Coso J, Gutiérrez-Hellín J, et al. Genetics and sports performance: the present and future in the identification of talent for sports based on DNA testing. *Eur J Appl Physiol.* 2022;122(8):1811-1830. doi:10.1007/s00421-022-04945-z
35. Vlahovich N, Fricker PA, Brown MA, Hughes D. Ethics of genetic testing and research in sport: a position statement from the Australian Institute of Sport. *Br J Sports Med.* 2017;51(1):5-11. doi:10.1136/bjsports-2016-096661
36. Egondi T, Kyobutungi C, Ng N, Muindi K, Oti S, Vijver SVd, Ettarh R, Rocklöv J. Community Perceptions of Air Pollution and Related Health Risks in Nairobi Slums. *International Journal of Environmental Research and Public Health.* 2013; 10(10):4851-4868. <https://doi.org/10.3390/ijerph10104851>
37. Ahmad H, Halim H. Determining Sample Size for Research Activities. *Selangor Business Review* [Internet]. 1Dec.2017 [cited 20Oct.2023];2(1):20-4. Available from: <https://sbr.journals.unisel.edu.my/ojs/index.php/sbr/article/view/12>
38. Varley I, Patel S, Williams AG, Hennis PJ. The current use, and opinions of elite athletes and support staff in relation to genetic testing in elite sport within the UK. *Biol Sport.* 2018;35(1):13-19. doi:10.5114/biolSport.2018.70747
39. Gray B, Semsarian C. Utility of genetic testing in athletes. *Clin Cardiol.* 2020;43(8):915-920. doi:10.1002/clc.23289
40. German JB, Zivkovic AM, Dallas DC, Smilowitz JT. Nutrigenomics and personalized diets: What will they mean for food?. *Annu Rev Food Sci Technol.* 2011;2:97-123. doi:10.1146/annurev.food.102308.124147
41. Karvela M, Golden CT, Bell N, Martin-Li S, Bedzo-Nutakor J, Bosnic N, et al. Assessment of the impact of a personalised nutrition intervention in impaired glucose regulation over 26 weeks: a randomised controlled trial. *Scientific Reports* [Internet]. 2024 Mar 5;14(1). Available from: <https://doi.org/10.1038/s41598-024-55105-6>
42. Park SH, Choi HK, Park JH, Hwang JT. Current insights into genome-based personalized nutrition technology: a patent review. *Frontiers in Nutrition* [Internet]. 2024 Jan 22;11. Available from: <https://doi.org/10.3389/fnut.2024.1346144>
43. Cha E, Kim KH, Erlen JA. Translation of scales in cross-cultural research: Issues and techniques. *Journal of Advanced Nursing.* 2007;58(4):386–95. doi:10.1111/j.1365-2648.2007.04242.x
44. Taber, K.S. The Use of Cronbach’s Alpha When Developing and Reporting Research Instruments in Science Education. *Res Sci Educ,* 2018; 48: 1273–1296 (2018). <https://doi.org/10.1007/s11165-016-9602-2>